# Statistical Models to Support Assessment and Decision-making in Stockpile Stewardship

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The LANL Statistical Sciences Group (CCS-6) has a long-standing effort in research and applied methods to support the assessment of conventional and nuclear weapon stockpiles. Our work is focused on tracking and trending of stockpile parameter data streams, statistics-based quantification of margins and uncertainties (QMU), age-aware models for reliability with quantified uncertainty, and resource allocation. Our goal is to provide improved confidence in future weapons reliability, safety, and performance. Some of the projects that are currently supported are:

- Integrated Reliability Methodology Projects leveraged with the DOE/DOD Joint Munitions Program:
    — Munitions Stockpile Reliability Assessment
    — Complex System Health Assessment
- Surveillance Transformation
- Data Provenance
- Quantification of Margins and Uncertainties
- Quantitative Surveillance Metric Development



*Fig. 1. Notional fault tree diagram for detonator performance.*
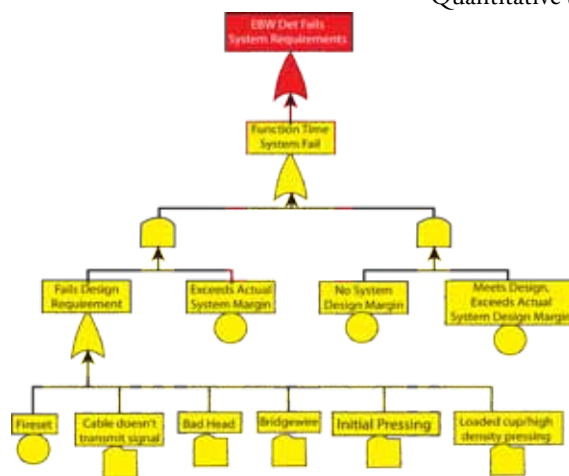
We briefly describe selected work supported by these projects.

Integrated Reliability Methodology (IRM) supports a wide range of projects including system health assessment and software tools. One focus area of application has been developing methodology for new detonator designs. The approach uses fault trees (see Fig. 1) and reliability block diagrams to characterize detonator performance by the performance of key subcomponents [1]. This essentially breaks down component-level functionality into the functionality, performance, and potential failure of events of key subcomponents. Having such information on components in existing and new designs allows us to better focus testing and helps determine priorities for improved understanding in the future.

Resource allocation methods are supported by IRM, and these methods mesh across elements in our work. Resource allocation focuses on assessing future data collection strategies for their projected improvement in the precision of system reliability estimates. This involves integrating the mathematical and computational methods necessary to connect integrated system assessments into a cost-benefit framework that can be used to compare different data collection strategies before the resources are spent and determine their anticipated utility. The results of this type of analysis can help determine how future resources should best be spent to understand system reliability and as part of improving weapon system surveillance planning (see Fig. 2)[2].

Surveillance transformation includes methodology for stockpile evaluation, age-aware assessments, and assessments of critical stockpile parameters. A major portion of the work is statistical modeling and evaluation for tracking and trending of surveillance data. In one specific application, statisticians are using advanced Bayesian hierarchical models for populations of shapes to model contours of the high-explosives parts in the stockpiles. This approach distinguishes between variation in as-built parts, instantaneous damage due to disassembly, and gradual aging (see Fig. 3). The approach also considers variation in the stockpile population, uncertainty in the stockpile averages, and measurement error. Analyses such as these can be used to provide input in the form of populations of contours under various assumptions, including extrapolating into the future, for the purpose of uncertainty quantification studies using physics codes [3].

Data provenance is concerned with managing large-scale, data-intensive projects that are a backbone of the weapons complex. The weapons complex collects a vast amount of data. Central to the ability to obtain and use the increasingly large amounts of data within the surveillance community is the need for tracking and
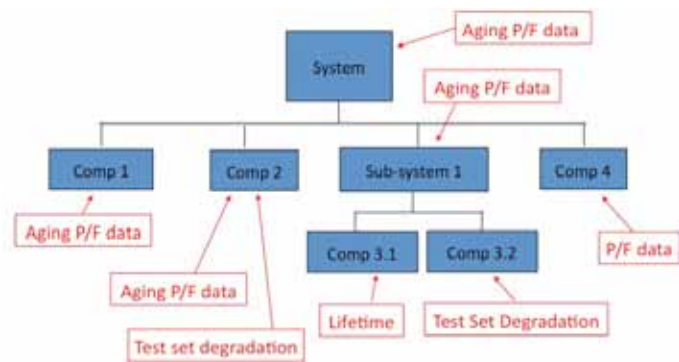
*Fig. 2. Resource allocation for improved reliability with different types of data.*
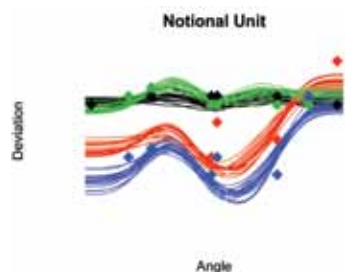


*Fig. 3. Bayesian hierarchical modeling of population shapes for contours.*

validation of the origins of the data. The term data provenance refers to the process of tracing and recording the origins of data and its movement between persons, locations, or databases. Focusing on the integrity of the data can allow for better evaluation of the value of the information and can help identify and/or resolve any discrepancies that may arise. For surveillance data analysis, it is essential to know exactly what data one is working with, where the data came from, whether or not the data have been validated, and any other information vital to the appropriate use of the data. This project worked with the Product Realization Integrated Digital Enterprise (PRIDE) program to develop a procedure to validate and track the evolution of data sets at LANL and at other DOE facilities. The team for the pilot project of this work received a Los Alamos Awards Program (LAAP) recognition. The project will facilitate the sharing of data within the nuclear weapons community.

Our QMU effort focuses on sensitivity and performance studies. We have developed methodologies for combining separate tests, and physics and engineering codes to map the effect of input variation and aging effects on performance [4]. We have created new methods for combining data from surveillance and experiments with physics simulations to provide performance-based lifetime assessments. The CCS-6 QMU work received a 2008 Defense Programs Award of Excellence.

We are involved with the development of a quantitative surveillance metric for confidence assessment of stockpile health [5]. The aging nuclear stockpile presents new challenges in our ability to develop and execute effective surveillance activities. Our work develops a tool to assist in the understanding of stockpile health. This is a statistical uncertainty model for reliability aging with an awareness of the consequences of sample size reduction and risks of various sampling rates for surveillance. This metric characterizes the uncertainty of stockpile reliability over time and can be used to help manage surveillance programs. We have also established methods for assessing the risks of sampling rates for surveillance [6] and quantifying reliability uncertainty, a joint project with Sandia National Laboratories (California and New Mexico) [7,8]. The goal is to integrate expert knowledge with summarized surveillance data. This approach supports balancing cost of data with precision of stockpile reliability estimates.

Through this broad range of applied work that encompasses developing methods and software tools, data collection strategies, and implementing solutions, CCS-6 supports stockpile stewardship. The group works to apply best practices to improve the understanding of weapon assessment and to support decision-making about the enduring stockpile.

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